

Amendment to the Claims

This listing of the Claims will replace all prior versions and listings of the claims in this patent application.

Listing of the Claims

1. (currently amended) A method for fabricating IC's comprising the following steps:

- (a) providing a substrate with an insulating layer over the substrate;
- (b) providing a first level of conducting material defined and embedded in the insulating layer over the substrate;
- (c) depositing an intermetal dielectric layer over the insulating layer;
- (d) forming a bi-layered hard mask, ~~two hard mask layers of undoped silicate glass, SiC or SiN, over the intermetal dielectric layer, the bi-layered hard mask comprising a first hard mask layer HM1 overlying a second hard mask layer HM2;~~
- (e) patterning the intermetal dielectric layer and hard mask layers, and etching to form via openings extending through the intermetal dielectric layer and the hard mask layers;
- (f) forming a layer of via-fill material of bottom anti-reflective coating with photoresist over the intermetal dielectric layer, the via-fill material ~~and filling the via openings with photoresist;~~
- (g) patterning the via-fill material, intermetal dielectric layer and hard mask layers, and etching to form trench openings; and

(h) ~~stripping-off the via-fill material after forming the trench openings, all photoresist,~~ thus forming open trench and open via regions for subsequent conducting metal fill.

2. (original) The method of claim 1, wherein said substrate is semiconductor single crystal silicon or an IC module.

3. (currently amended) The method of claim 1, wherein said conducting material is ~~selected from following group comprised of:~~ metal wiring or contacts of Cu, AlCu alloys, AlCuSi alloys, W, polysilicon, silicide, or P-N junction diffusion regions.

4. (currently amended) The method of claim 1 wherein the insulating layer and intermetal dielectric layer are comprised of: silicon dioxide, silicon oxide, undoped silicate glass, Fluorine doped Oxide, Carbon-doped Oxide, Organic based low-k dielectric, ~~and or~~ porous low-k dielectric, where the IMD, inter-metal dielectric, film thickness is in a range approximately from 0.2 to 2 microns.

5. (currently amended) The method of claim 1, wherein said bi-layered hard mask is comprised of:

~~HM1—HM2~~

~~——USG/SiC or SiN~~

~~——USG/SiC~~

~~——USG/SiC~~

~~——USG/SiC~~

where ~~USG, undoped silicate glass for first hard mask layer HM1 layer, hard mask top layer, of undoped silicate glass or also can be a conventional SiO<sub>2</sub> film of having a thickness in the~~ range from 1000 to 2000 Angstroms; and  
HM2, ~~second hard mask bottom layer HM2 of silicon carbide or silicon nitride having an etch, is a selective dielectric layer (Selectivity of ~3-5) for~~ with respect to said first hard mask layer HM1 etch, with etch stop on HM2, the HM2 ~~and having a thickness of~~ is between approximately 300 to 600 Angstroms thick.

6. (previously presented) The method of claim 1, wherein said photoresist is comprised of organic material, thickness ranges from thickness from 500 to 3,000 Angstroms, and etched forming trench openings using a reverse tone process.

7. (currently amended) The method of claim 1, wherein the intermetal dielectric layer and hard mask layers are etched to form trench openings by reactive ion etch, RIE, processing scheme for trench etch using the following RIE gas mixtures:

Step 1: CF<sub>4</sub> / Ar based for etching ~~BARC~~ an opening in said via-fill material;

Step 2: CF<sub>4</sub> / CHF<sub>3</sub> / Ar based for HM1 etch;

Step 3: N<sub>2</sub> / O<sub>2</sub> based for etching via-fill material recess;

Step 4: CF<sub>4</sub> / N<sub>2</sub> / O<sub>2</sub> based for ~~HM2 and IMD etching~~ HM2 and said intermetal dielectric;

Step 5: O<sub>2</sub> based for Ashing; and

Step 6: CHF<sub>3</sub> / N<sub>2</sub> based for bottom etch stop layer etch.

8. (currently amended) The method of claim 1, wherein multilevel structures are fabricating by repeating steps (b) through (h), ~~described above.~~

9. (previously presented) A method of fabricating an integrated circuit with a dual damascene process using a bi-layer hard mask, the method comprising the following steps:

- (a) providing a substrate with an insulating layer over the substrate;
- (b) providing a first level of conducting material defined and embedded in the insulating layer over the substrate;
- (c) depositing an intermetal dielectric layer over the insulating layer;
- (d) forming a bi-layered hard mask, two hard mask layers, over the intermetal dielectric layer, the bi-layered hard mask comprising a first hard mask layer HM1 overlying a second hard mask layer HM2;
- (e) patterning the intermetal dielectric layer and hard mask layers, and etching to form via openings extending through the intermetal dielectric layer and the hard mask layers;
- (f) forming a layer of via-fill material of bottom anti-reflective coating with photoresist over the intermetal dielectric layer, the via-fill material and filling the via openings ~~with photoresist;~~
- (g) patterning the via-fill material, intermetal dielectric layer and hard mask layers, and etching to form trench openings;
- (h) stripping-off the via-fill material after forming the trench openings, ~~all photoresist,~~ forming open trench and open via regions;
- (i) depositing a copper seed layer in the trench openings and via openings;
- (j) forming an excess of copper metal over the copper seed layer; and

(k) planarizing the excess copper back, thus forming inlaid copper in the trench and via openings for contact vias and interconnect wiring.

10. (original) The method of claim 9, wherein said substrate is semiconductor single crystal silicon or an IC module.

11. (currently amended) The method of claim 9, wherein said conducting material is selected from following group comprised of: metal wiring or contacts of Cu, AlCu alloys, AlCuSi alloys, W, polysilicon, silicide, or P-N junction diffusion regions.

12. (currently amended) The method of claim 9 wherein the insulating layer and intermetal dielectric layer are comprised of: silicon dioxide, silicon oxide, undoped silicate glass, Fluorine doped Oxide, Carbon-doped Oxide, Organic based low-k dielectric, and or porous low-k dielectric, where the IMD, inter-metal dielectric, film thickness is in a range approximately from 0.2 to 2 microns.

13. (currently amended) The method of claim 9, wherein said bi-layered hard mask is comprised of:

~~HM1—HM2~~

~~——USG / SiC or SiN~~

~~——USG / SiC~~

~~——USG / SiC~~

~~USG / SiC~~

~~where USG, a first hard mask HM1 layer of undoped silicate glass for HM1 layer, hard mask top layer, also can be a conventional or SiO<sub>2</sub> film of having a thickness in the range from 1000 to 2000 Angstroms; and~~

~~HM2; a second hard mask bottom layer HM2 of silicon carbide or silicon nitride having an etch; is a selective dielectric layer (Selectivity of ~3-5 with respect to said first hard mask layer HM1) for HM1 etch, with etch stop on HM2, the HM2 is and having a thickness of between approximately 300 to 600 Angstroms thick;~~

14. (previously presented) The method of claim 9, wherein said photoresist is comprised of organic material, thickness ranges from thickness from 500 to 3,000 Angstroms, and etched forming trench openings using a reverse tone process.

15. (currently amended) The method of claim 9, wherein the intermetal dielectric layer and hard mask layers are etched to form trench openings by reactive ion etch, RIE, processing scheme for trench etch using the following RIE gas mixtures:

Step 1: CF<sub>4</sub> / Ar based for etching ~~BARC~~ an opening in said via-fill material;

Step 2: CF<sub>4</sub> / CHF<sub>3</sub> / Ar based for HM1 etch;

Step 3: N<sub>2</sub> / O<sub>2</sub> based for etching via-fill material recess;

Step 4: CF<sub>4</sub> / N<sub>2</sub> / O<sub>2</sub> based for ~~HM2 and IMD~~ etching of said HM2 and said intermetal dielectric;

Step 5: O<sub>2</sub> based for Ashing; and

Step 6: CHF<sub>3</sub> / N<sub>2</sub> based for bottom etch stop layer etch.

16. (original) The method of claim 9, further comprising depositing and defining a copper seed layer, in the via and trench openings, comprised of copper, with thickness maximum of approximately 3,000 Angstroms.

17. (original) The method of claim 9, further comprising depositing a conducting metal fill of electrochemically deposited copper upon a copper seed layer, in the via and trench openings, with thickness maximum of approximately 20,000 Angstroms, forming an excess of copper over the vias and trenches.

18. (original) The method of claim 9, further comprising planarizing an excess of copper over the vias and trenches by chemical mechanical polish, milling, ion milling, and/or etching, forming inlaid dual damascene conducting metal interconnects and contact vias in the vias and trenches.

19. (currently amended) The method of claim 9, wherein multilevel structures are fabricating by repeating steps (b) through (k); ~~described above.~~

20. (previously presented) A method of fabricating an integrated circuit with a dual damascene process for applications in MOSFET CMOS memory and logic devices, using a bi-layer hard mask, the method comprising the following steps:

(a) providing a substrate with an insulating layer over the substrate;

- (b) providing a first level of conducting material defined and embedded in the insulating layer over the substrate;
- (c) depositing an intermetal dielectric layer over the insulating layer;
- (d) forming a bi-layered hard mask, two hard mask layers, over the intermetal dielectric layer, the bi-layered hard mask comprising a first hard mask layer HM1 overlying a second hard mask layer HM2;
- (e) patterning the intermetal dielectric layer and hard mask layers, and etching to form via openings extending through the intermetal dielectric layer and the hard mask layers;
- (f) forming a layer of via-fill material of bottom anti-reflective coating with photoresist over the intermetal dielectric layer, the via-fill material ~~and filling the via openings with photoresist;~~
- (g) patterning the via-fill material, intermetal dielectric layer and hard mask layers, and etching to form trench openings;
- (h) stripping-off the via-fill material after forming the trench openings, ~~all photoresist,~~ forming open trench and open via regions;
- (i) depositing a copper seed layer in the trench openings and via openings;
- (j) forming an excess of copper metal over the copper seed layer; and
- (k) planarizing the excess copper back, thus forming inlaid copper in the trench and via openings for contact vias and interconnect wiring.

21. (original) The method of claim 20, wherein said substrate is semiconductor single crystal silicon or an IC module.



22. (currently amended) The method of claim 20, wherein said conducting material is selected from following group comprised of: metal wiring or contacts of Cu, AlCu alloys, AlCuSi alloys, W, polysilicon, silicide, or P-N junction diffusion regions.

23. (currently amended) The method of claim 20 wherein the insulating layer and intermetal dielectric layer are comprised of: silicon dioxide, silicon oxide, undoped silicate glass, Fluorine doped Oxide, Carbon-doped Oxide, Organic based low-k dielectric, and/or porous low-k dielectric, where the IMD, inter-metal dielectric, film thickness is in a range approximately from 0.2 to 2 microns.

24. (currently amended) The method of claim 20, wherein said bi-layered hard mask is comprised of:

~~HM1—HM2~~

~~——USG / SiC or SiN~~

~~——USG / SiC~~

~~——USG / SiC~~

~~——USG / SiC~~

~~where USG, a first hard mask layer HM1 of undoped silicate glass for HM1 layer, hard mask top layer, also can be a conventional or SiO<sub>2</sub> film of having a thickness in the range from 1000 to 2000 Angstroms; and~~

~~HM2, a second hard mask bottom layer HM2 of silicon carbide or silicon nitride having, is a selective dielectric layer (an etch Selectivity of ~3-5) for HM1 etch, with etch stop on HM2, the~~

HM2 is with respect to said first hard mask layer HM1 and having a thickness of between  
approximately 300 to 600 Angstroms thick.

25. (previously presented) The method of claim 20, wherein said photoresist is comprised of organic material, thickness ranges from thickness from 500 to 3,000 Angstroms, and etched forming trench openings using a reverse tone process.

26. (currently amended) The method of claim 20, wherein the intermetal dielectric layer and hard mask layers are etched to form trench openings by reactive ion etch, RIE, processing scheme for trench etch using the following RIE gas mixtures:

Step 1:  $\text{CF}_4$  / Ar based for etching ~~BARC~~ an opening in said via-fill material;

Step 2:  $\text{CF}_4$  /  $\text{CHF}_3$  / Ar based for HM1 etch;

Step 3:  $\text{N}_2$  /  $\text{O}_2$  based for etching via-fill material recess;

Step 4:  $\text{CF}_4$  /  $\text{N}_2$  /  $\text{O}_2$  based for ~~HM2 and IMD~~ etching said HM2 and said intermetal dielectric;

Step 5:  $\text{O}_2$  based for Ashing; and

Step 6:  $\text{CHF}_3$  /  $\text{N}_2$  based for bottom etch stop layer etch.

27. (original) The method of claim 20, further comprising depositing and defining a copper seed layer, in the via and trench openings, comprised of copper, with thickness maximum of approximately 3,000 Angstroms.

28. (original) The method of claim 20, further comprising depositing a conducting metal fill of electrochemically deposited copper upon a copper seed layer, in the via and trench openings, with thickness maximum of approximately 20,000 Angstroms, forming an excess of copper over the vias and trenches.

29. (original) The method of claim 20, further comprising planarizing an excess of copper over the vias and trenches by chemical mechanical polish, milling, ion milling, and/or etching, forming inlaid dual damascene conducting metal interconnects and contact vias in the vias and trenches.

30. (currently amended) The method of claim 20, wherein multilevel structures are fabricating by repeating steps (b) through (k), ~~described above.~~

31-32. (canceled)

33. (new) The method according to claim 1, further comprising recessing the via-fill material to control fence or sub-trench profile, wherein the recessing can be performed after etching the via-fill material to form trench openings and/or after etching HM1 to form trench openings.

34. (new) The method according to claim 9, further comprising recessing the via-fill material to control fence or sub-trench profile, wherein the recessing can be performed after etching the via-fill material to form trench openings and/or after etching HM1 to form trench openings.

35. (new) The method according to claim 20, further comprising recessing the via-fill material to control fence or sub-trench profile, wherein the recessing can be performed after etching the via-fill material to form trench openings and/or after etching HM1 to form trench openings.